The World-Wide Wireless Web

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Abstract — **The world-wide wireless web is the promise of delivering the desktop experience to the mobile society. This is a promise of seamless connectivity and multimedia interactivity while on the move. This promise is driving convergence of demand for high speed wireless data with the demand for greater convenience, greater access, and greater, more visual and dynamic content, all without compromising the security and bit error rate performance that we have come to expect in the wired world.**

I. Introduction

Despite the turmoil surrounding the recent collapse of the dot.com virtual economy, the rise of the popularity and pervasiveness of the internet ranks as one of the key technological trends driving market growth for affordable multi-media capable, and connected PC's. At the same time the growth of the wireless market has been fueled by another key application, voice-only cellular phones. Although both the PC and Cellular market have experienced a phenomenal growth, there has been little or no overlap between the two markets, until now.

Cellular has filled a need to be able to be in contact while on the move – hence, mobile communication. The internet has filled several needs: keeping in contact via email, getting information to customers, subject matter research, as well as some "needs" that customers didn't realize until they saw the potential: the ability to chat with people they've never met, from places they've never been, making new friends and creating a global community based on similar interests but disparate locations. Similarly, the ability to create websites that share interests, knowledge, and creative endeavors with others filled an underserved, unrecognized gap for individual expression.

The worldwide wireless web is just now coming into existence, with the desktop internet experience setting a high level of expectation from consumers. The display may necessarily be physically smaller, but the multimedia content, user friendliness, and impatience with latency remain. The location of a desktop is precisely known, whereas the location of a mobile portable device may be precisely what the person wants to determine as he or she wanders through a new city. Let's explore some of the needs, known and unrecognized, that the worldwide wireless web can fulfill and the technological challenges and opportunities it brings to the engineering community working to bring this level of connectivity to the consumers. The needs can be related to the various aspects of a mobile person's life:

II. APPLICATIONS

A. Business / Enterprise

Business people, engineers, doctors and other professionals, sales people, entrepreneurs all need to stay connected- with customers –suppliers – and employees. This need is particularly underserved for people who are on the move. Some helpful applications for business people are the ability to remotely obtain:

* Ready answers to questions
* Quick Resolution to Problems
* What-if Analysis for Decision making
* Marketing Presentations updated on the spot
* Global Collaboration example: software
* Record and share thoughts and promising ideas as they arise – rather than try to recall them weeks later.

B. Consumer

Pagers and cellular phones followed similar paths in adoption: early versions were adopted by professionals such as doctors as a means to keep in touch remotely; later, these products were adopted by people for use in their daily life. Applications of the wireless web in personal life might include;

* Keeping in Touch – via voice or text
* Adding the additional dimension of visual communication
* Re-using the visuals for entertainment
* Expanding entertainment to interactive games
* Remote control… really remote
* Instant Information / Order tickets...
* Creative Expression – sharing audio and visual creations with friends and family

C. Academia

In academia, the adoption to personal computers and to the web has been perhaps more influential and pervasive than the adoption to wireless communication. The merging of these into the worldwide wireless web will enable applications to academic life that might include:

* Interactive learning experiences – a virtual classroom, supplemented by…
* Simulation and Modeling – providing the means for engineering students to remotely interact with a model of system, or a design, or a manufacturing facility while also interacting with other students…or providing the means for history students to virtually experience a key moment in history, together.
* Remote Access to Materials – course materials, libraries anywhere in the world..
* Team Projects / Cooperative Efforts
* Collaboration – Research, Reports, Publications – and extending the possibilities for Global teamwork, with universities, professors, and graduate students halfway around the world.
* Record and share thoughts and ideas as they arise, rather than try to recall the ideas later.

D. Global Collaboration

The potential for remote collaboration, and even global collaboration has significant ramifications for business and academic endeavors. The potential for people to teamwork remotely using a variety of media – visual, audio, text – in a way that is supportive and comfortable opens new possibilities in creative development and productivity bringing about unprecedented levels of efficiency and productivity to the person and the work team. Furthermore, the communication does not only connect people, but connects people to machines, and machines to machines. These machines will be more than mere access points for database searches and retrievals, they will play a critical role in providing timely, useful information.

III. TECHNOLOGY

Let's examine some key technology needs and challenges that need to be addressed in order to bring the desktop experience to the mobile person. First, on the air interface side (RF/IF), with so many wireless standards and frequency bands around the globe, a multi-mode, multi-band unit with wideband (>1MHz) capability for high speed data access is the minimum requirement to get the "always on" experience on the move. Furthermore, several wireless LAN protocols need to be supported by the unit in order to accommodate local connectivity needs ranging from "talking" to peripherals such as printers and cameras, to communicating multi-media files with other units in an ad-hoc local network, without having to bear the latency and cost of the cellular protocol. Finally, future units will need to be GPS capable in order to enable location based services, from E911 to mapping services, to location based M-commerce (example, downloading electronic coupons from a nearby business).
On the human interface side, multi-media information transfer and processing will drive demand for larger, color displays with better resolution, stereo audio, and video capture, compression and processing.

While the fundamental technologies exist to accommodate all of these features, the challenge is to get them into similar form factor, cost, weight, and battery drain as current 2G mobile phones. For example, nothing short of a two-hour talk time will impress the consumer. Furthermore, the consumer sees little perceived value around the multi-mode, multi-band capability; these capabilities are simply expected.

These requirements drive the RF/IF performance requirements to new limits. A cellular unit with WLAN and GPS capability will require well over 600 parts, a very complex system. New technologies and/or architectures will need to be innovated to drive the parts count below 300 in order to start driving consumer type volumes.

III. PHYSICAL LAYER

Wireless connectivity involves the remote terminals and an infrastructure to connect with. Figure 1 shows the rates and ranges available today and in the near future for various means of data communication. Some of the means involve wire, some fiber, and some wireless. Generally, the longer distance, higher data rates involve fiber optic communication.

WAN	LAN	Home/PAN	
OC768 40G OC192 10G OC48 2.5G **ACTS Satellite 622K**	Gigabit Ethernet 1G	FiberChannel Gigastar,Cameralink LVDS FastWide SCSI	3GIO Hypertransport Infiniband USB 1 Infiniband PCI USB2 FireWire
	Ethernet 100 VDSL 52	**UWB ≤100** **802.11A 54->32**	PCI **Real-time video (compressed)**
	T3 45 Cable 27-56 Ethernet 10	Powerline 13 **802.11B 11**	SCSI-1 PCMCIA USB 1.1
	DSL 10 **3G Stationary 2M** T1, SDSL 1.544 **3G Mobile,EDGE.384** **GPRS .115**	Phoneline 10 Cable Modem 1-2 **Bluetooth 1** **Satellite: .5** **802.15.4 .25**	**Internet** **Spyder 1** **Aura .25**

Figure 1. Data rates for various physical layers, allocated according to distance ranging from WAN to the PC level.

As illustrated with Figure 2, one reason that fiber optic systems predominate in long distance, high data rate WAN systems is the severe disadvantage wireless suffers in terms of bit error rate for any given Signal/Noise ratio. Efforts are underway to develop a satellite communication system with 622 Mb/s data rates – but even through the relatively clear path of between satellites and earth antennas, the raw bit error rate is only about 1e-5. The effective bit error rate will be improved to about 1e-11 through the magic of error correction techniques – still short of the 1e-12 to 1e-13 bit error rates enjoyed comparatively effortlessly by fiber optic systems.

Wireless communication is more effectively and perhaps more appropriately engaged for shorter distances and mobile situations rather communication between fixed points like metropolitan areas. Here, the arena involves communication with an infrastructure, such as in 3G using WCMA, or communication with an ad-hoc infrastructure, such as the 802.11X, Bluetooth, and emerging Ultra Wideband (UWB) networks and piconetworks. Key requirements for mobile communications continue to be low cost, small size, and low power for long battery life. High data rates are an additional requirement for the wireless internet.

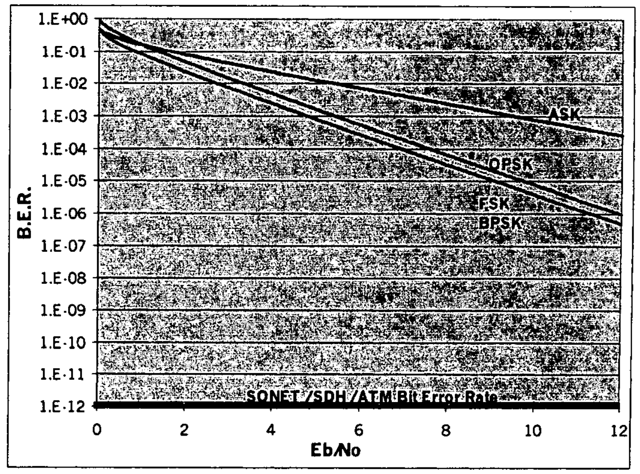

Figure 2. Bit error rates vs Eb/No (proportional to S/N ratio) for various wireless systems – with bit error rates for SONET superimposed.

Some keys to high data rate wireless connectivity are

- Low bit error rates
- High spectral efficiency
- Robustness to multipath, doppler effect and other issues in mobile environments.

The need for high spectral efficiency is derived from FCC constraints, and can be met by approaches such as:

- Frequency Hopping Spread Spectrum
- Direct Sequence Spread Spectrum
- OFDM
- Ultra WideBand (UWB)

Frequency Hopping Spread Sprectrum (FHSS) is used in Bluetooth for piconets. Direct Sequence Spread Spectrum (DSSS) is used in 802.11B as well as in CDMA and Wideband CDMA (WCDMA) adapted in various 3G implementations. Orthogonal Frequency Division Multiplexing (OFDM) is used in 802.11A for higher data rates wireless local area networks. UltraWideBand (UWB) was recently given limited approval by the FCC, and provides the potential for data rates that perhaps can approach 100 Mbps.

Frequency spectra from FHSS, DSSS and OFDM are compared in figure 3. The high spectral efficiency is evident, and increases roughly in the order listed – OFDM and DSSS having higher spectral efficiency than FHSS, and UWB treating the frequency spectrum as if it were irrelevant…within constraints set by the FCC (from about 3 GHz to 10 GHz).

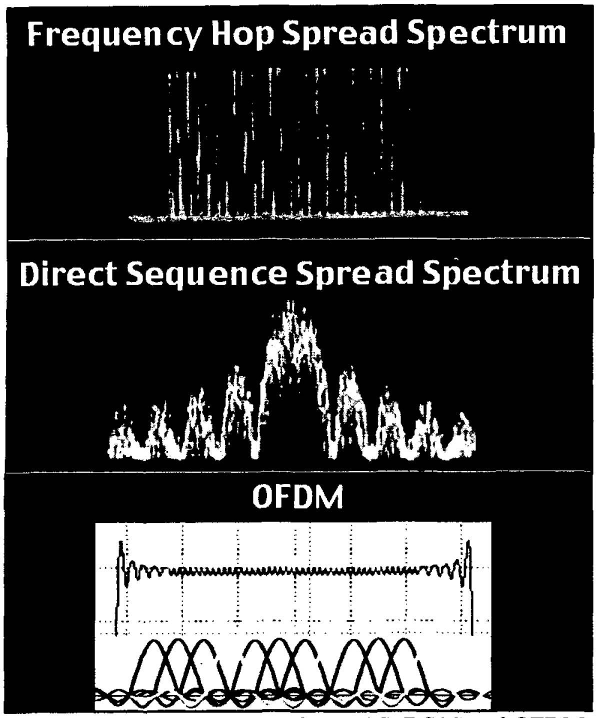

Figure 3. Frequency Spectra for FHSS, DSSS and OFDM.

The continuing trend towards low cost, consistent with a remarkably steep learning curve, drive considerations of alternative architectural and integration approaches with an eye towards eliminating or integrating costly components either on chip or in the package or module.

The low power, long battery life requirement for portable devices needs to be addressed both at the system level and through much of the electronics. RFIC design engineers have found a special fondness for process technologies providing high frequency transistors with low leakage, and low parasitic capacitance, not to mention good matching.

The apparent need to meet multiple wireless standards and multiple frequencies in the same handheld unit adds complexity and works against the drives towards low cost and low power consumption. Cellular standards are generally multi-frequency, and often multi-mode; moreover, the desire to combine cellular communication with Wireless LAN or a piconet and perhaps with location services via GPS add conveniences and services – perhaps alerting you when you are near your favorite restaurant chain in an unfamiliar city – but at the expense of additional circuitry and impedance matching components, not to mention additional DSP and memory requirements on the baseband side.

V. Conclusion

The worldwide wireless web is emerging, amid high expectations from potential customers and difficult challenges. RFIC design and wireless system engineers face challenges involve achieving high data rates in mobile environments, connecting using multiple protocols at multiple frequencies, while seeking lower costs and low power consumption, in order to connect the mobile world in a worldwide wireless web. The range of potential applications indicates that the potential impact on people, on enterprises, and on academia could be remarkable.